CLAIMS

[1] A light-collecting device which collects incident light, comprising:

a substrate into which the incident light is incident; and

above said substrate, a plurality of light-transmitting films formed in a region into which the incident light is incident,

wherein said light-transmitting film forms a zone in which a width of each zone is equal to or shorter than a wavelength of the incident light,

each zone shares a center point which is located at a position displaced from the center of said device, and

the plurality of said light-transmitting films form an effective refractive index distribution.

[2] The light-collecting device according to Claim 1,

wherein light is collected in a center of a plane made of said light-transmitting films, the light being incident at an angle asymmetrical to the center of the plane made of said light-transmitting films.

[3] The light-collecting device according to Claim 1,

wherein an amount of phase change of the incident light $\phi(x)$ depending on a distance x in an in-plane direction approximately satisfies the following equation,

$$\phi(x) = Ax^2 + Bx\sin\theta + 2m\pi$$

where θ is an incident angle of the incident light, A and B are predetermined constants, and m is a natural number.

[4] The light-collecting device according to Claim 1,

wherein

$$\Delta n(x) = \Delta n_{\max}\left[\phi(x)/2\pi + C\right]$$

is satisfied, where $\Delta n_{\max}$ is a difference of refractive indexes

between one of said light-transmitting films and a light-incoming side medium, $\Delta n(x)$ is a difference of refractive indexes between another one of said light-transmitting films and the light-incoming side medium at a position x, and C is a constant.

[5] The light-collecting device according to Claim 1,

wherein heights of said light-transmitting films are constant in a direction normal to said light-transmitting films.

[6] The light-collecting device according to Claim 1,

wherein each of said light-transmitting films includes one of TiO_2, ZrO_2, Nb_2O_5, Ta_2O_5, Si_3N_4 and Si_2N_3.

[7] The light-collecting device according to Claim 1,

wherein each of said light-transmitting films includes one of SiO_2 doped with B or P, that is Boro-Phospho Silicated Glass, and Teraethoxy Silane.

[8] The light-collecting device according to Claim 1,

wherein each of said light-transmitting films includes one of benzocyclobutene, polymethymethacrylate, polyamide and polyimide.

[9] A solid-state imaging apparatus comprising arranged unit pixels, each of which includes a respective light-collecting device,

wherein said light-collecting device comprises:

a substrate into which the incident light is incident; and

above said substrate, a plurality of light-transmitting films formed in a region into which the incident light is incident,

wherein said light-transmitting film forms a zone in which a width of each zone is equal to or shorter than a wavelength of the incident light,

each zone shares a center point which is located at a position displaced from the center of said device, and

the plurality of said light-transmitting films form an effective refractive index distribution.

[10] The solid-state imaging apparatus according to Claim 9,

wherein an off-centered light-transmitting film is also formed in an area shared by one light-collecting device and another light-collecting device in an adjacent unit pixel.

[11] The solid-state imaging apparatus according to Claim 9, at least comprising:

a first unit pixel for a first color light out of the incident light; and

a second unit pixel for a second color light which has a typical wavelength that is different from a typical wavelength of the first color light;

wherein said first unit pixel includes a first light-collecting device, and

said second unit pixel includes a second light-collecting device in which a focal length of the second color light is equal to a focal length of the first color light in said first light-collecting devices.

[12] The solid-state imaging apparatus according to Claim 9,

wherein a focal point is set at a predetermined position by controlling a refractive index distribution of said light-transmitting film.

[13] The solid-state imaging apparatus according to Claim 9,

wherein each of said unit pixels further includes a light-collecting lens on a light-outgoing side of said light-collecting

device.

[14] The solid-state imaging apparatus according to Claim 9, wherein a refractive index distribution of said light-transmitting film is different between light-collecting devices of said unit pixels located in a center of a plane on which said unit pixels are formed and light-collecting devices of said unit pixels located in the periphery of the plane.

[15] The solid-state imaging apparatus according to Claim 9, wherein in said unit pixels located in a center of a plane on which said unit pixels are formed, a central axis of each of said light-receiving devices is placed to match a central axis of each of said light-collecting devices, and

in said unit pixels located in the periphery of the center of the plane, a central axis of each of said light-receiving devices and a central axis of each of said light-collecting devices are placed toward the center of the plane.